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Effect of Nitriding on Wear Behavior of Tool Steels:

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Abstract— The effect of nitriding on wear behavior of various tool steels containing more than 1% of carbon and several different alloy materials is studied. The steels IS-T110W6Cr4, JIS-SK3 and AISI – M35 steels were used as samples and are heat treated followed by nitriding at 540^{o}C. The specimens were characterized by means of glow discharge optical spectrometry, Brinell, Rockwell and Vickers hardness test, Micro Vickers for case depth, rubbing velocity test (pin on disc). The nitriding has successfully increased the case hardness and wear resistance properties of less alloyed material IS – T110W6Cr4 and JIS – SK3 where as it failed to achieve expected hardness for the highly alloyed material AISI – M35.

Keywords— Nitriding, Tool steels, wear , hardness

I. INTRODUCTION

The positive effects of surface treatments like nitriding on the fatigue and wear properties of structural steel have been known for several decades. Tools and components used in the severe working environment must have excellent corrosion resistance and wear resistance. Consequently, the structural steel of those components should be always surface modified to provide these needed properties. The surfaces of these components are required to attain high hardness values to resist wear, and the inner cores still need to have high toughness strength. Therefore, various methods, such as nitriding, carburizing, ceramic coating and thermal chemical treatments, have been devised to improve the surface mechanical properties of the components. Among those surface treatment processes, the gas nitriding methods have been used extensively to enhance the mechanical properties of steel components. During the gas nitriding treatment, nitrogen, which is provided by the catalytic dissociation of ammonia, diffuses through the steel surface to form a concentration gradient as well as nitride precipitates in the nitriding case. The solid solution of nitrogen in the metal substrate and the nitride precipitates are responsible for the increase of hardness and compressive macro stresses in the diffusion layer.

For the nitriding to be effective the carbon content in a steel should be optimum and to be around 1 %. But the alloy elements will also play a major role while nitriding a steel. Normally the tool steels will be having more carbon as well as more alloy elements. Afif and Badr [1] studied the nitriding effect on the plain carbon steel B St-3 sp and found to be effective for that steel. Further Nana and Xiang [2] investigated the effect of process parameters on the nitriding of grey cast iron. They noted that the nitrogen concentration decreases with increase in process temperature. This proved that for effective nitriding an optimum temperature can be used.
Shu-Hung *et al.* [3] performed the gas nitriding on SACM steel and found the effects of nitriding on SACM 645 Steel. They concluded that the effect of nitriding on the SACM 645 steel for 48 to 72 hours were found to be more yielding than other process time. Şeyda Polat *et al.* [4] performed the gas nitriding on hot work tool steel [4] and found that the effect was positive. This proves that the presence of tungsten will not influence the nitride layer. It is very important that all the tool steels which work under heavy load and at high temperature should be alloyed with tungsten for more hot strength and hardness.

The aim of present work is to provide a brief effect of gas nitriding on these tool steels and the steels which are similar to these. The paper describes the process parameters used and the tests that have been done for inspecting the wear behavior of these steels (IS – T110W6Cr4, JIS – Sk3 and AISI – M35).

II. Experimental Procedures

The chemical composition (wt. %) of the specimens (IS – T110W6Cr4, JIS – SK3 and AISI – M35) analyzed by a glow-discharge optical emission spectroscope (Optical Emission Spectrometer BAIRD – DV 6E) is listed in Table 1.

Table 1Chemical compositions of materials in weight %

Name	C	Si	Mn	Cr	W	Mo	V	Co
T110W6Cr4	1.05	0.28	0.91	0.94	1.26	-	-	-
SK3	1.00	0.24	0.22	-	-	-	-	-
M35	0.91	0.32	0.16	4.07	6.59	4.6	2.03	4.97

The specimens were oil quenched and tempered to the substrate hardness of 45, 56 and 62 HRC before nitriding. Treatments were carried out in a gas nitriding furnace at 540°C for 72 h. The chamber was filled with NH_3 gas at a constant flow rate.

The cross-sectional microstructure of the specimens was revealed by fine-grounding the surface of specimens using abrasive papers to a 500 fine finish and the surface is etched using a chemical solution of 95 ml alcohol +5 ml HNO_3 also known as nital solution, and was observed on an optical microscope (NEOPHOT 32). Micro hardness was measured by using a Vickers micro hardness tester with the applied load of 100 g. The wear resistance of the specimens was investigated on a pin on disc rubbing velocity tester. A normal load of 1Kg (9.81N) was applied for 10 minutes at a constant speed of 300 rpm.

III. Results and Discussions

A. *Hardness of Materials*

The hardness of materials before all the treatment is found out by Brinell hardness tester according to the Indian Standard ISO – 1500:2000 [8], with a 5mm ball and a load of 3000Kg. The hardness observed are shown below on figure 1

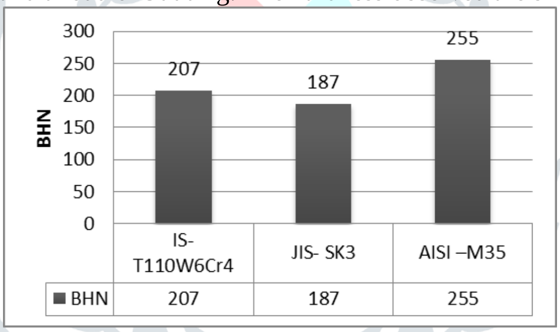


Figure 1 Hardness of Raw Materials in BHN (5/3000 30S)

The materials were hardened at suitable temperatures, 840ºC for JIS – SK3 (oil quenched), 860ºC for IS – T110W6Cr4 (oil quenched) and 1120ºC for AISI – M35 (air cooled), followed by 1 hour tempering at 180ºC in salt bath for both JIS – Sk3 and IS – T110W6Cr4 and AISI – M35 was triple tempered at 560ºC in salt bath for 2 hours for each tempering. The hardness of these materials were found using Rockwell hardness tester as per Indian Standard ISO – 1586:2000 [7]. The hardness observed is as shown on figure 2

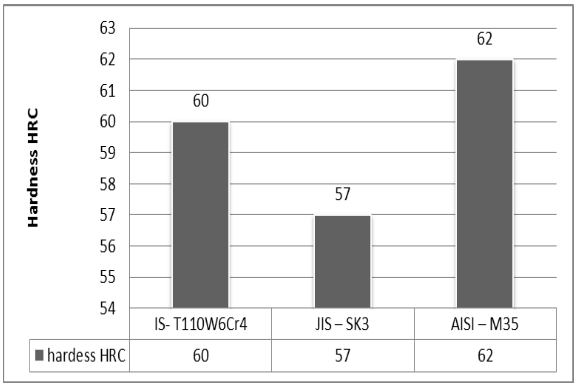


Figure 2 Hardness of Heat Treated Materials in HRC

The heat treatment was followed by nitriding. The specimens were kept at 540ºC at gas nitriding chamber with a constant flow rate for 72 hours. Then the case and core hardness are taken using a Vickers Hardness tester. The procedure is as per the Indian Standard ISO 6507-1:2005 [10]. The case and core hardness found are as in figure .3

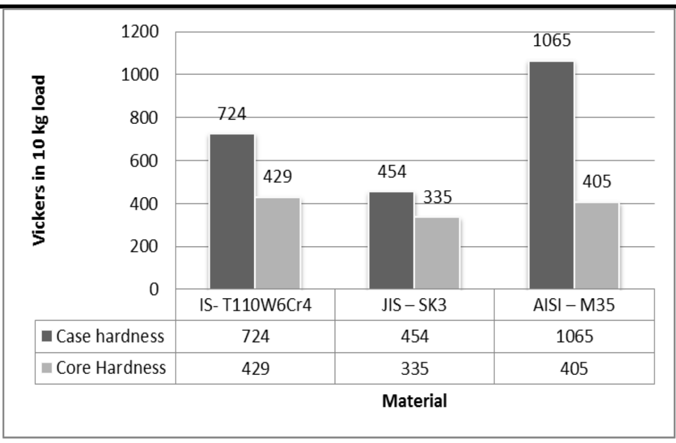
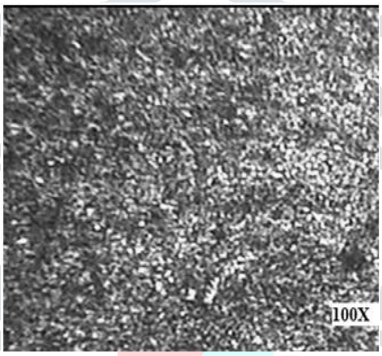


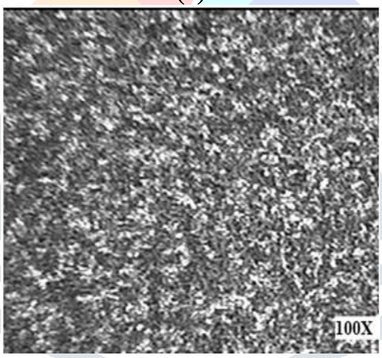
Figure 3 Hardness of nitrided material (case and Core) in HV10

B. Microstructure

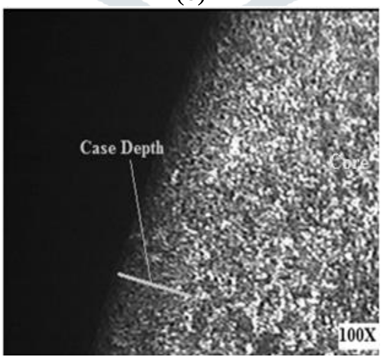
The microstructure was taken by optical microscope (NEOPHOT 32). The specimens were mechanically fine ground with 500 fine emery abrasive sheets followed by polishing and then etched with 95ml alcohol + 5ml HNO_3 (Nital) solution. The microstructure was taken as per Indian standard ISO 6508-1:2000 [12].



(a)

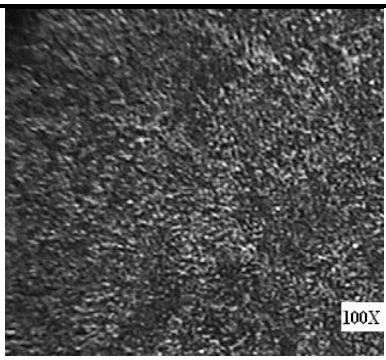


(b)

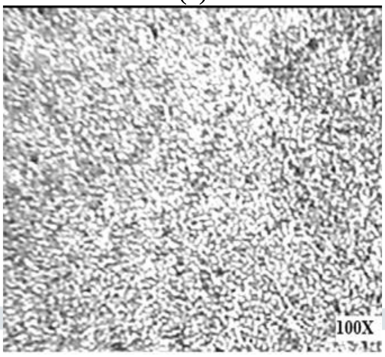


(c)

Figure 4 (a) annealed IS – T110W6Cr4 steel, distribution of secondary carbides in perlite matrix can be seen (b) hardened and tempered IS – T110W6Cr4 steel, distribution of secondary carbides can be seen in martensite matrix (c) nitrided IS – T110W6Cr4 steel, nitrided case depth can be seen in martensite matrix.



(a)



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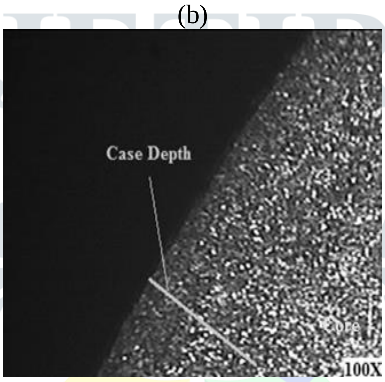
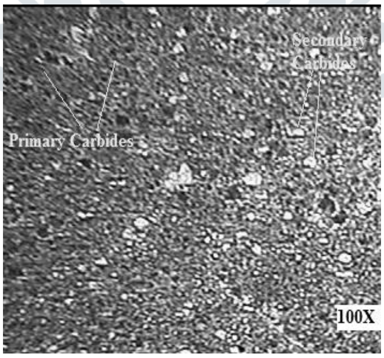
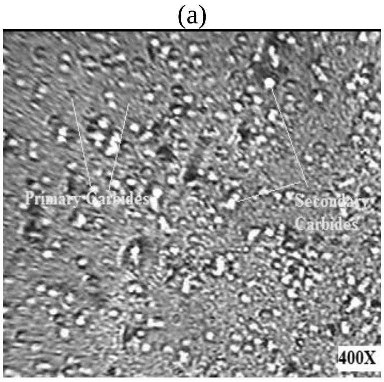


(c)

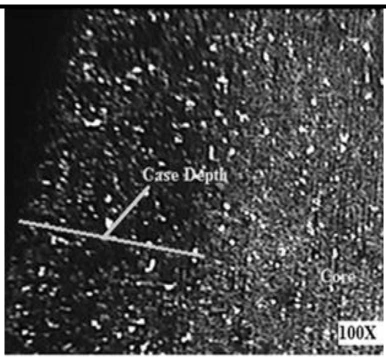
Figure 5 (a) annealed JIS – SK3 steel, proper distribution of secondary carbides in pearlite matrix can be seen (b) hardened and tempered JIS – SK3 steel, proper distribution of secondary carbides in martensite matrix can be seen. (c) Nitrided JIS – SK3 steel, nitrided case depth can be seen in martensite matrix.



(a)



(b)



(c)

Figure 6 (a) annealed AISI – M35 steel, proper distribution of primary and secondary carbides in pearlite matrix can be seen (b) hardened and tempered AISI – M35 steel, proper distribution of primary and secondary carbides can be seen (c) nitrided AISI – M35 steel, nitrided case depth can be seen in martensite matrix.

C. Case Hardness

The case hardness was tested in Digital Micro Vickers hardness testing machine and an interval of 0.1mm was taken for each readings of hardness. And for case depth a value of 500HV0.1 is considered which is considered as suited hardness for most cutting tool and equipment.
The testing was done as per Indian Standard, ISO-6416:1988 [6].

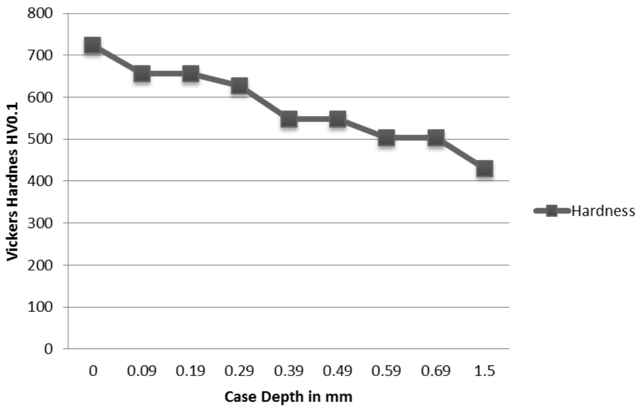


Figure 7 case depth of IS – T110W6Cr4 done on Micro Vickers hardness tester

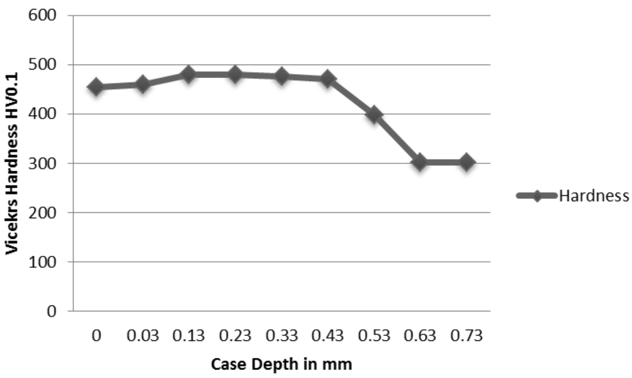


Figure 8 case depth of JIS – SK3 done on Micro Vickers hardness tester

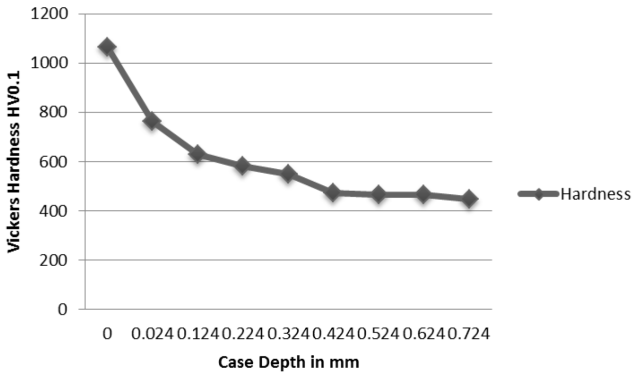


Figure 9 case depth of AISI – M35 done on Micro Vickers hardness tester

D. Wear Resistance

The rubbing velocity wear test was conducted as per ASTM G99 Standard. The RPM was set at 300 and the load was 1Kg (10N) and was run for 10 minutes for each sample. The percentage of weight loss of the each material is shown as in the below figure 10

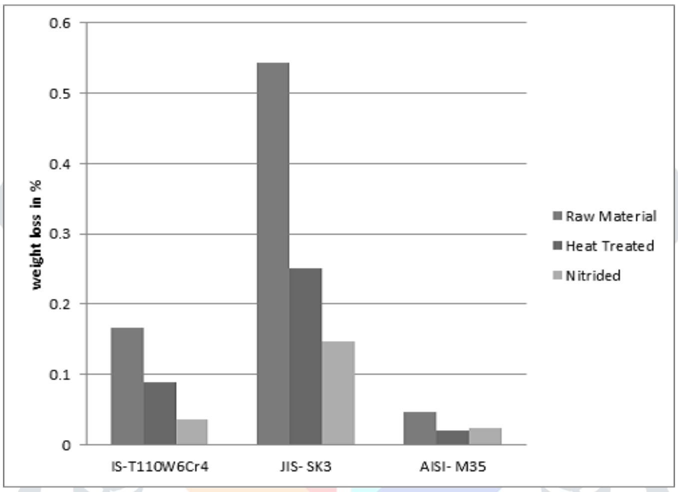


Figure 10 Percentage weight loss comparisons of all specimens

IV. Conclusions

JIS- SK3 material wear rate and weight loss is more in all the cases (Raw material, Heat treated and Nitrided) compared to AISI – M35 because of unalloyed JIS – SK3 and presence of 6% Tungsten and 5% Cobalt.

By observing the hardness values of raw material from the graph, heat treated and nitrided, it has come to a conclusion that the case hardness remained superior in AISI –M35 than JIS – SK3.

For measuring case depth, taking the cut off value of 500HV0.1 by seeing the graph for AISI – M35 material, up to 0.4mm of case is achieved a hardness value of 500HV0.1 and for material IS – T110W6Cr4, we have achieved 0.63mm of case and for material JIS – SK3, we could not achieve 500HV0.1.

It is found that the rate of nitrogen diffusion in material IS – T110W6Cr4 is better than AISI – M35.

Decarburization was found in JIS – SK3.

V. Refecences

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[12] “Macroscopic examination by etching with strong mineral acids” ISO 6508-1:2000